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Preparation and Examination of Thin Sections of Set Cements.*

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(Of the Building Research Station)

The study of thin sections of set cement has not attracted so much attention as that of sections of cement clinker. This is due probably in part to the greater difficulty of preparing satisfactory sections, as these are required to be exceptionally thin, and in part to the less definite results which may be obtained from them. Nevertheless the examination of thin sections of set cements is a useful means of studying the hydration process. In the course of chemical investigations on Portland cement in progress at the Building Research Station, a considerable number of thin sections of hydrated cements has been prepared and examined. Since the technique evolved for set cement differs to some extent from that in normal usage, an account of these methods is given in the present paper, together with some general observations which have been made on the cements. Some notes are included on the preparation and examination of sections stained by various methods and with different colouring materials.

Preparation of Thin Sections.

The cements, gauged neat with water to a plastic consistency, were cast in 1in. cube moulds, stored for one day in moist air, removed from the moulds, and stored in water until required for test. In making the sections, a portion was sawn from the cube and reduced to a slice about ⅛in. thick. One surface was

ground either dry with coarse emery cloth or with No. 220 grit carborundum abrasive and kerosene as lubricant on a rotating metal disk, and then cleaned and ground on flat glass plates† using "Sira" abrasive and liquid paraffin. When the ground surface of the slice was perfectly flat and free from scratches, it was again cleaned thoroughly, using kerosene and a moderately stiff brush, and dried. Canada balsam (filtered) was heated on a glass slide to the proper consistency and the slice mounted on the slide by the "hinge" method, with the usual precautions against trapped air bubbles.

The preliminary grinding of the reverse side of the slice was carried out on a revolving metal disk using No. 220 grit carborundum and kerosene, but it was found necessary to discontinue coarse grinding at an earlier stage than is normal in preparing petrological sections and to remove all traces of the abrasive by cleaning with kerosene. The lubricants softened the Canada balsam slightly, and grit which had become embedded had to be removed by scaling the surface of the balsam with a knife, followed by a further cleaning of the whole section. The thickness of the section was finally reduced by grinding on glass plates with "Sira" abrasive and liquid paraffin lubricant. This part of the operation was very slow and tedious because of the extra thickness which had to be removed, but it was not found possible to reduce the time by employing coarser abrasives since by so doing the specimen was invariably rendered useless. After grinding, the section was washed and dried as before and the cover glass mounted. A convenient method for the latter operation is to support the section over a hot plate by means of two strips of glass, so that the balsam softens slightly. Meanwhile a few drops of balsam on the cover glass were heated to a slightly less viscous condition than that used originally on the slide, and the cover glass lowered on to the slide by the "hinge" method. The finished section after cooling was washed in methylated spirit.

Examination of Thin Sections of Set Cement.

Specimens of different batches of Portland cements, at ages varying up to one year, have been examined under the microscope (x 375) in thin sections as described. The best results were obtained in sections ground to about half the usual thickness (i.e. ground to about 15–20 μ); sections of thickness greater than about 30μ have not been found to be of any great value for examination under the microscope.

When sections were prepared from any one batch of cement after hydration periods of 7, 14, 28 and 42 days, very little difference in structure was apparent between one section and another, i.e. the effect of ageing was not well shown in the sections, although ageing does affect the strength and degree of hydration. Sections of material hydrated for one year, however, appeared to show a slightly more uniform structure than those hydrated for the shorter periods mentioned. On the other hand, differences were observed between sections from different

† Circular glass plates, 8in. diameter by ½in. thick, used for this purpose can be kept perfectly level by grinding them together at intervals; the abrasive is reduced to a greater degree of fineness and uniformity by grinding between the plates.

batches of cement even when these were prepared after similar hydration periods. These differences were largely in the amount of hydrated iron-containing compounds present, in the degree of uniformity of the section, and in the amount of unhydrated material remaining. Certain characteristics common to sections from all batches, at all ages, were evident.

Unhydrated Portland cement powder is made up of grains of varying size, of which about 10 per cent. by weight may be of diameter greater than 80μ. The crystals in the cement are not usually so large as this, and the coarse grains are

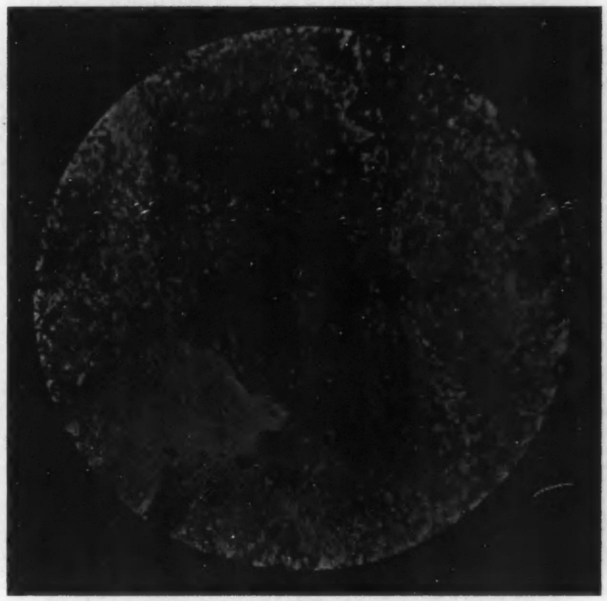

Fig. 1.
Cluster of unhydrated $2CaO.SiO_2$ crystals in hydrated cement.
Ordinary light. Magnification × 375.

therefore made up of clusters of crystals. In the set cement sections, unhydrated material, easily identified as unchanged $2CaO.SiO_2$, was observed at all ages. This material occurred most often in clusters of crystals surrounded by hydrated cement, and it is therefore assumed that these were originally coarse grains in the cement made up of a cluster of $2CaO.SiO_2$ crystals. In ordinary light they were often somewhat more brown in colour than the remainder of the section. An example of this type of cluster is shown in Fig. 1. The outlines of roughly circular grains of various sizes were also observed, often in fairly good relief against the background, and as before it is assumed that these were originally

Fig. 2.
Section of hydrated cement.
Ordinary light. Magnification × 375.

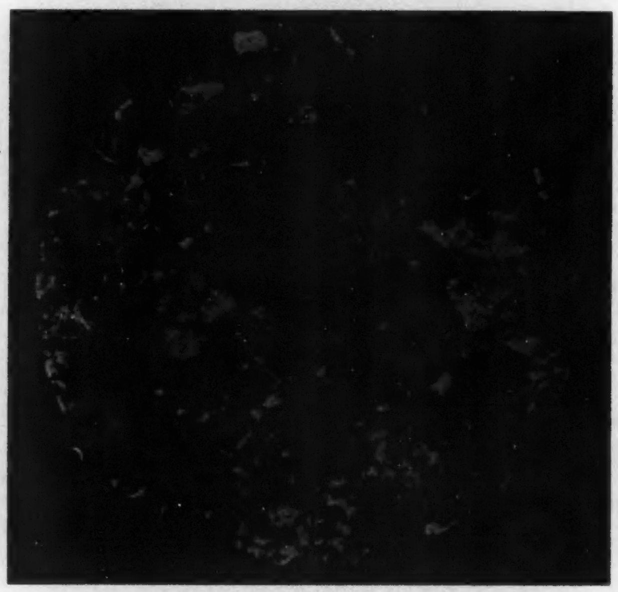

Fig. 3.
Section of hydrated cement.
Crossed Nicols. Magnification × 375.

grains in the unhydrated cement powder. Their degree of hydration apparently varied considerably, some of the grains being isotropic, whilst others showed a birefringent unchanged centre portion which graded to an outer border of isotropic material. In a few isolated cases, with the thinner sections, grains having a sharp boundary between the outer isotropic border and the inner birefringent core were observed. An unusually large elongated grain of this type is shown at the south-west edge of Fig. 2 in the position indicated by an arrow. In Fig. 3, which is of the same field as Fig. 2, but under crossed nicols, the birefringent core with isotropic border may be seen clearly. It is assumed that hydration has penetrated completely through the grain when the latter is isotropic, and that partial penetration only has taken place where the centre is birefringent. Variations of this type from completely hydrated to unhydrated grains were observed. Unhydrated $3CaO.SiO_2$ could not be detected even at the age of seven days, the shortest period of hydration examined. This, however, may well be due to the low birefringence of this compound rendering the detection of unhydrated cores almost impossible.

The ground mass of the set cement section was somewhat heterogeneous. It contained, in addition to the crystal forms mentioned, irregularly shaped small crystals or groups of crystals of calcium hydroxide which had apparently crystallised in the interstices between the grains. The smallest of these crystals appeared only as pinpoints of light under crossed nicols, and the larger ones usually showed a sweeping extinction. The amount of calcium hydroxide present appeared to vary with different cements. Large, single, well developed crystals of the compound appeared occasionally, usually in pores in the section, and in some cases there was difficulty in deciding whether roughly circular grains were calcium hydroxide or unhydrated $2CaO.SiO_2$. Material apparently containing the iron oxide from the cement appeared as irregular masses, brown to almost opaque. The opaque material in Fig. 2 is of this type. In particular, a large mass is shown in the centre of the plate.

The observed phenomena were particularly well emphasised in sections made from a coarse cement residue consisting entirely of material remaining on a 170-mesh sieve. This coarse-grained cement hardened slowly and gave very porous sections in which a large part of the interstitial material between the grains consisted of calcium hydroxide, and in which the pores also very frequently contained well developed calcium hydroxide crystals. Illustrations of the latter are shown in Figs. 4 and 5. Sections after seven days showed a very open structure which became less open after 28 days, although still containing a considerable amount of unhydrated material.

Staining Methods.

Attempts have been made to stain the thin sections in order to differentiate more clearly between the various parts of the structure. In preliminary tests it was found that eosin was unsuitable for the purpose, while anthrapurpurine did not produce a sufficiently intense colour and tended to give too much general staining. Methylene blue stains silica gel, but not calcium silicate gels, and in

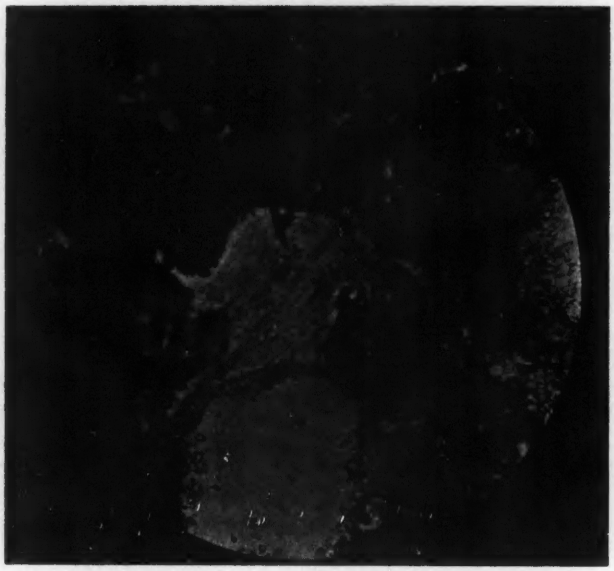

Fig. 4.
Large crystals of $Ca(OH)_2$ in a section of hydrated coarsely ground cement.
Ordinary light. Magnification × 375.

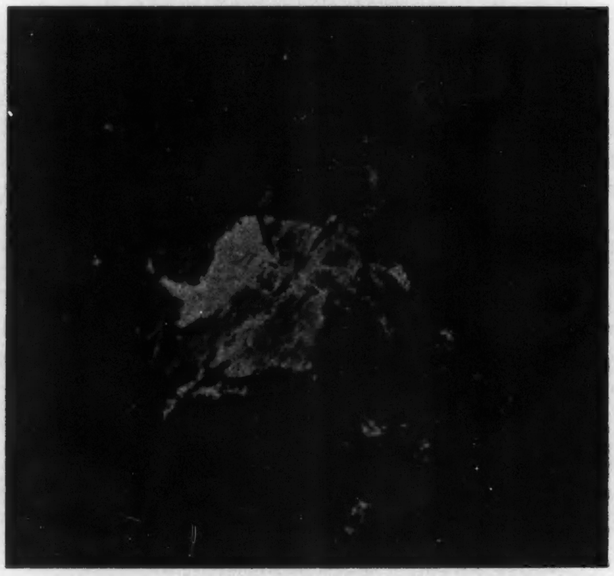

Fig. 5.
Large crystals of $Ca(OH)_2$ in a section of hydrated coarsely ground cement.
Crossed Nicols. Magnification × 375.

order to produce staining of the sections by this dye, it was necessary to cause a decomposition to silica gel on the surface of the calcium silicates. This was achieved by the addition of benzoic acid to the dye. Satisfactory staining was produced when the dye and acid were used in solution in alcohol; aqueous solutions caused destruction of the specimens.

The most satisfactory stain used was naphthol green B (the ferrous sodium salt of β naphthol β monosulphonic acid). F. Hundeshagen[1] recommends it for use in distinguishing between the carbonated and uncarbonated layers in concrete, but it may equally well be used for sections under the microscope.

In treating specimens for staining, the best results were obtained by coarse grinding with the dry emery cloth rather than with coarse abrasive and liquid paraffin. Fine grinding was carried out as described previously. Various methods for staining were attempted as follows:

(I) The naphthol green B was dissolved in the water used for mixing the cement cubes, and the sections were then made in the ordinary manner.

(II) The dye was dissolved in alcohol containing a little water and specimens were dyed by immersion during the grinding operation, the operation being varied as follows:—(*a*) After fine grinding the first side of the specimen, the slice was immersed in the dye solution for twelve hours. A little extra fine grinding was then given to the first side before continuing the normal process. (*b*) Slices were immersed in the dye solution after coarse grinding only, and fine grinding carried out subsequently. (*c*) The completed section was immersed in the dye solution just before finally mounting the cover glass.

Method II (*a*) was adopted for general use, since more uniformly stained and clear sections were obtained, and the operation presented fewer difficulties than other methods. In the case of method II (*c*) some difficulty was always experienced owing to the dye solution creeping under the section. This method differs from the others, in which the crystals are cut across after staining. In the completed sections prepared by methods I, II (*a*), and II (*b*), therefore, the stain will only appear on materials which it has completely penetrated, while crystals which have absorbed dye on their surfaces only will not appear to be stained. In practice, however, little difference was observed in the manner of staining by any of the methods. In all cases the dye was found to penetrate the gel, and the sections showed the gel ground mass stained green while the unhydrated material and large calcium hydroxide crystals were unstained. The small calcium hydroxide crystals in the ground mass were either unstained or showed rather less staining than the ground mass, but the differentiation in these cases was not very clear. Relatively heavy staining took place on the hydrated isotropic grains, particularly when seen in the thinner (15–20μ) sections.

Further attempts to differentiate between the compounds present, by staining the sections with mixtures of the dyes, did not lead to good results.

Although the appearance of the sections described differs somewhat from similar sections described by Kühl[2] the observations are not at variance with the generally accepted theory that hardening is due to gel formation. The slow rate of hydration of calcium orthosilicate is well confirmed by the presence of this compound in the unhydrated state after prolonged hydration periods. The methods described have not afforded evidence of the method of hydration of the aluminate or of the rôle played by gypsum in the hydration process.

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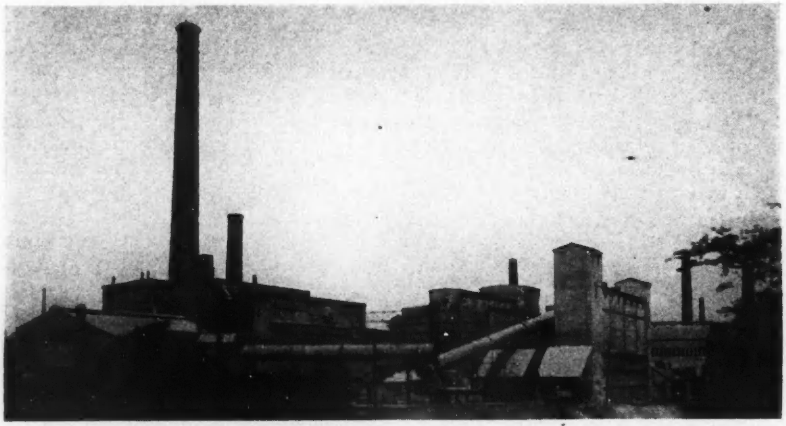
[2] KÜHL, H., *Cement Chemistry in Theory and Practice.* Translated by J. W. Christelow, London. 1931. (Concrete Publications, Ltd.) p. 31.



The Coltness Iron Company's Cement Works.

Extension of the Cement Works of the Coltness Iron Company, Ltd.—I.

By HENRY POOLEY, Jnr., B.Sc., M.Inst.C.E., M.I.Mech.E.,
CONSULTING ENGINEER FOR THE NEW WORKS.

THE blastfurnace Portland cement factory of the Coltness Iron Co., Ltd., is at Newmains, Lanarkshire. Before the war the Company operated an extensive blastfurnace plant, and in the very early days machinery was installed merely to mix and grind blastfurnace slag and lime, using the well-known process developed by Colloseus in Germany, but in general the quality of this old type of slag cement was not very uniform. The Company, therefore, installed a new plant, treating the materials as normal raw materials are treated in the manufacture of normal Portland cement on the dry process. The new plant, designed and supplied by Pfeiffer of Kaiserslautern, was completed just at the outbreak of hostilities in 1914, and produced true Portland cement clinker. To manufacture blastfurnace cement the clinker was mixed with granulated slag.

The Existing Works.

Fig. 1 is a diagrammatic outline of the works as it existed early in 1934. Limestone and slag entered at A and were crushed in jaw crushers and elevated to reinforced concrete bunkers arranged in pairs over two Pfeiffer "double hard" mills at B and C, operating in connection with separators. These four bunkers are now used to store the crushed material for the new grinding plant. A complicated system of conveyors, elevators, and the like transported the ground material to four reinforced concrete silos at D. Again, these four silos have been used for the storage and mixing of raw material in the new extensions. They

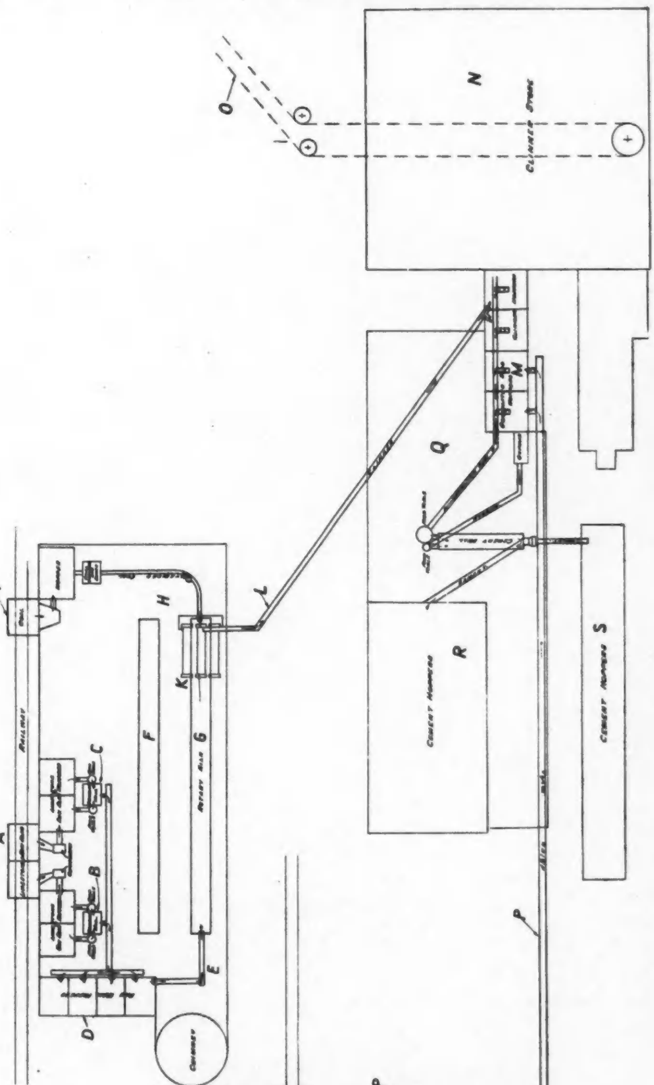


Fig. 1.—Diagrammatic Outline of Works as it existed in January, 1934.

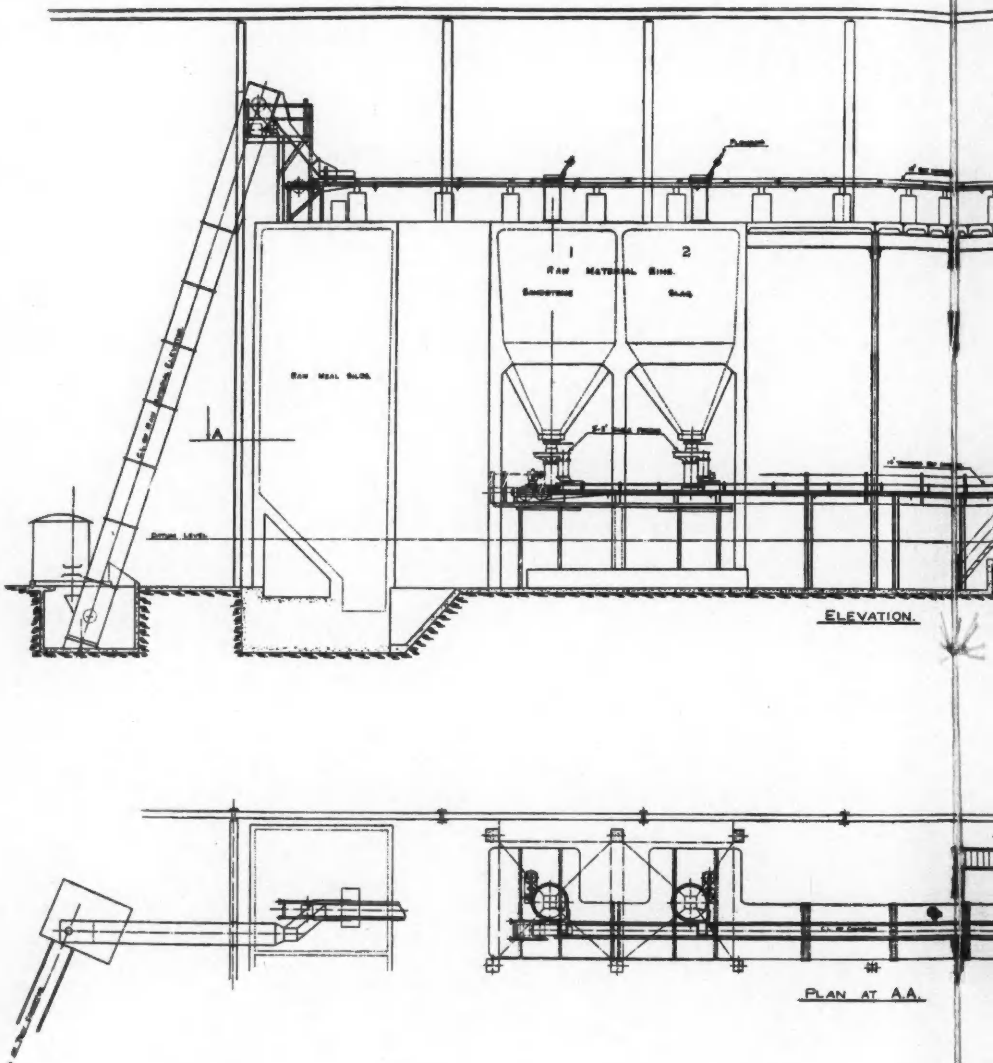
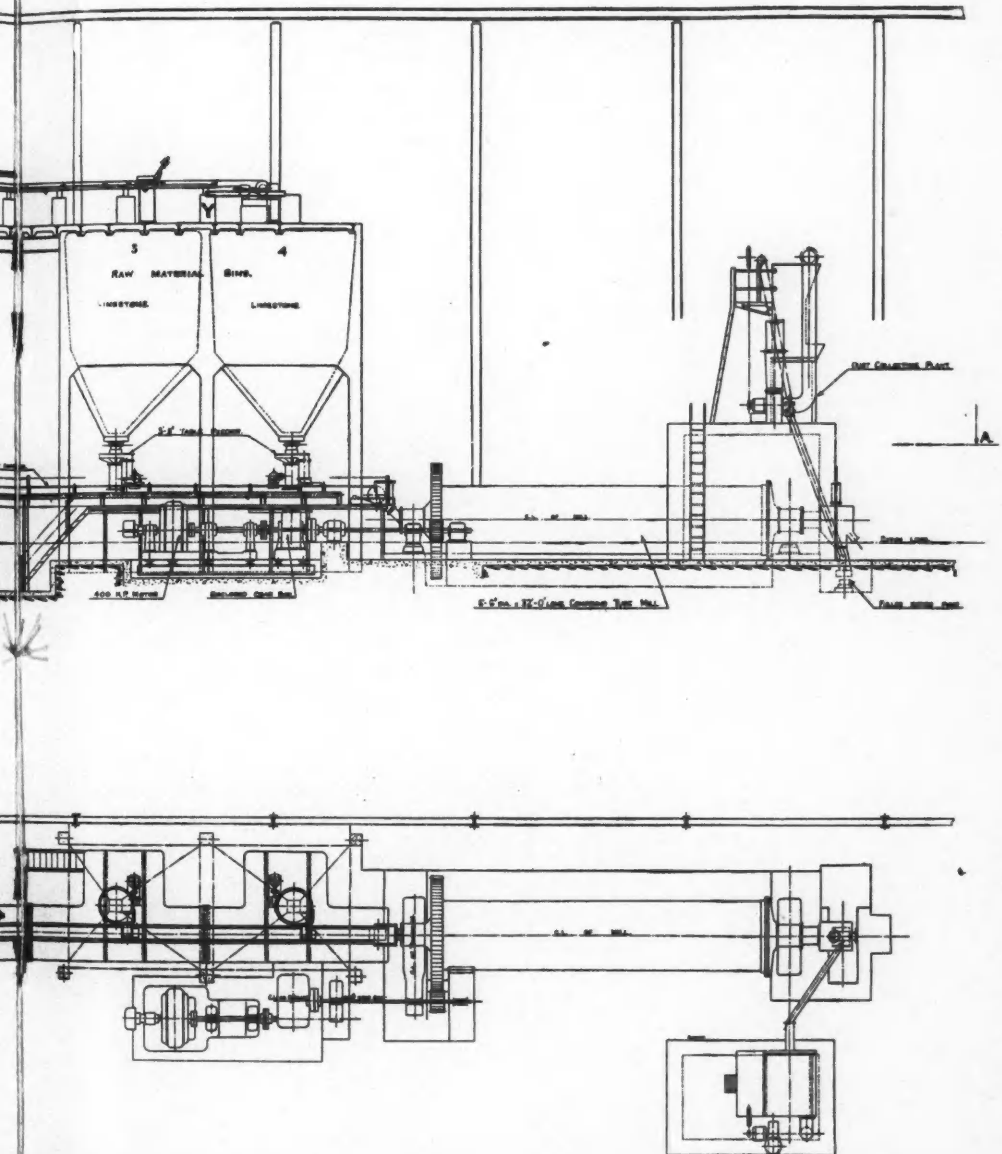


Fig. 2.—Arrangement of New



of New Raw Material Plant.

were previously fitted with extraction worms, and elevators and conveyors circulated the material for blending. The uniformity of the mix passing to the kiln was not good and necessitated extremely hard burning to produce the quality desired. All the machinery was driven by belting and countershafting, which was very complicated. When the raw meal was mixed as well as possible with this system, it was extracted from a silo and elevated directly to a paddle conveyor discharging it into the kiln feedpipe. The usual water spray (at E) was arranged to damp the material before entry to the kiln.

No. 2 kiln (G) was used. The original kiln (No. 1 situated at F), now disused, was about 115ft. long by 8ft. 2in. in diameter at the firing zone (which was about 33ft. long) by 6ft. diameter for the rest of the length. A separate double-shell type cooler 29ft. 6in. long by 5ft. 9in. and 4ft. 8in. in diameter was installed underneath. This kiln has not operated for many years.

No. 2 kiln was 131ft. long by 8ft. 2in. in diameter and parallel throughout its length, and was fitted with a Pfeiffer-type integral cooler. The clinker, after passing through the firing zone, fell through four ports equally spaced around the circumference of the shell and thence to four cooling cylinders (H) 26ft. 3in. long by 2ft. 7in. diameter, fastened to the kiln shell and rotating with it. The clinker in the coolers travelled in the opposite direction to the material in the kiln and was delivered at K. The clinker was then elevated to a hopper and taken by the ropeway L directly to the concrete clinker hoppers at M.

To reach the store N the clinker was first discharged in trucks and placed in the store by a second ropeway (O). One or more of the hoppers at M was used for granulated slag, conveyed thither by the conveyor P. The clinker and slag were fed to a shaker conveyor, the flow being regulated by feed tables in the hoppers, and taken to the grinding plant in the building Q. Originally the grinding was performed by Krupp ball and tube mills, but a few years ago these were replaced by a Smidth Unidan mill, 36ft. long by 6ft. 6in. in diameter. The finished cement was stored, mixed, packed, and despatched at R and S. The coal was discharged at T and dealt with in a Herbert Attritor (No. 12) located in the position shown and thence blown into the kiln.

The fineness of the raw meal produced by this arrangement was in the neighbourhood of 18 per cent. residue on the 170-mesh sieve, while the uniformity, as already indicated, left much to be desired. The output averaged just under four tons per hour, while the coal consumption was approximately 26/27 per cent. standard coal. The kiln exit-gas temperature, as normally in the case of a kiln of these dimensions and working under these conditions, was in the neighbourhood of 900 deg. F. or more, while the temperature of the clinker leaving the coolers was about 450 deg. F. With such coarse raw material, the burning was naturally very hard. The Pfeiffer cooling arrangements contained the germ of the ideas of cooling so well-known to-day.

Plan of Modernisation.

In spite of the fact that the Company's blastfurnaces have been shut down for the past ten years and it is now necessary to purchase slag, it was decided

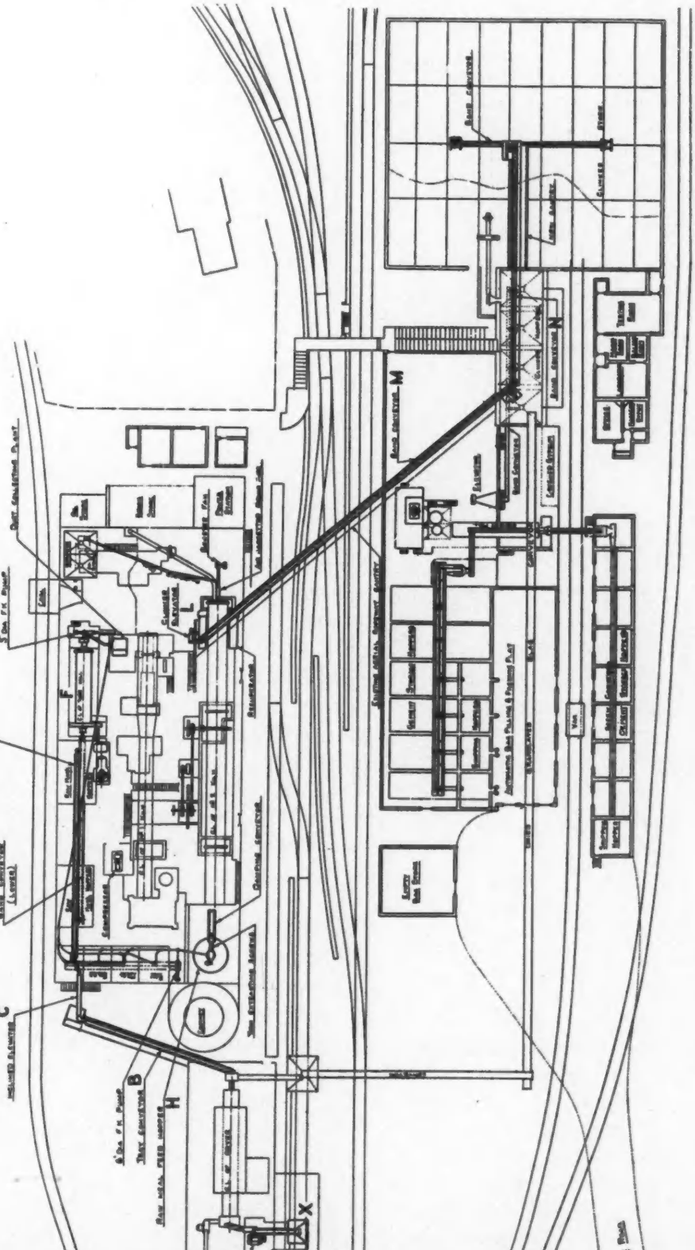


Fig. 3.—Arrangement of Plant showing improvements installed during 1934—these are heavily outlined in the drawing.

to modernise the cement plant by scrapping certain old machinery and introducing new plant and methods. To keep the cost of the alterations within the prescribed limits and at the same time accomplish the desired results was not simple when dealing with a mass of complicated belt drives and out-of-date machinery, although the matter was simplified by the excellence of the original lay-out, the space available in the buildings, and the substantial nature of the buildings. The alterations indicated in Fig. 3 were decided upon and installed. In outline these comprised first, new raw material crushing and handling arrangements at A, B, C, and D for the introduction of limestone, slag, and sandstone into the existing crushed stone hoppers originally used to feed the Pfeiffer "double hard" mills. Then extracting arrangements for the crushed stone hoppers were fitted, together with a new grinding unit, at F, and an entirely new system of transport for the raw meal was installed. Also, new mixing arrangements were installed, together with a proper feed to the kiln at H. The lower two sections of the kiln were removed and replaced, and a new recuperator added at A. An elevator at L was installed to take the clinker to a band conveyor (M) running in the existing gantry which previously carried the ropeway transporting the clinker. A second band conveyor at N was installed to distribute the clinker in the existing clinker hoppers or directly to the clinker store as shown in the drawing. In the store a reversible conveyor running at right angles to the last was introduced to distribute the clinker. This outline indicates the extent of the modernisation of the plant, and it was felt that in this way a good deal had been done to improve the quality of the clinker, decrease costs, and simplify the working of the plant.

Perhaps the most important alteration made was in connection with the handling and mixing of the dry raw powder for burning. One of the disadvantages of the dry process in the past has been that it was impossible, under normal conditions, to maintain as uniform a mix passing forward to the kiln as when using the wet system. It was (and is) possible to maintain, without undue difficulty, a calcium carbonate content of the wet slurry not varying much more than, say, 0.15 per cent. on each side of the desired figure. This uniformity can be regularly maintained, and thus, other things being equal, the quality of the cement being manufactured by the wet process was in general more uniform than that made by the dry process. Now, however, this statement can no longer be maintained on account of improved methods of blending dry powders.

The Fuller-Kinyon method was chosen in this case, and when it is efficiently operating this system will maintain a regularity of mix similar to the wet process. Indeed, in this case, soon after the installation and before the men were accustomed to the new ideas and machinery, the mix had already greatly improved and maintained its proportion within 0.4 per cent. After some months of operation the mix is maintained with a variation of 0.15 per cent. A somewhat detailed description of this operation is given later, as readers in this country are in general not so familiar with the dry process, and where, owing largely to the nature of most of the raw materials, the wet process is almost universally used.

Raw Materials.

The raw materials are limestone, slag, and sandstone. All the materials are delivered by rail and are dumped from trucks at point X on Fig. 3. Here a new reinforced concrete hopper supplies a new apron feeder manufactured by Boby and Co. This feeder is 18in. wide and is supported at 16ft. centres; it is driven by a 3 h.p. motor through enclosed worm-reduction gearing. The feeder consists of overlapping mild steel trays 18in. wide and ¼in. thick, each having a flanged cast-iron roller at each end running on angles protected by wearing strips. The trays are attached to a single strand of standard flat-link-type chain passing over chilled cast-iron sprocket wheels.

The feeder discharges either directly into the boot of an elevator feeding the drier (which is the case when the material not required to be crushed is fed to the system or when the flap valve is turned), or to one of the original Pfeiffer crushers taken from its old position. The elevator was also transferred from its position in the old plant and 18in. buckets were fitted. The limestone, in pieces of approximately 4in. cube downwards, is reduced by the crusher to about 1½in. and under. The three materials are fed to the system at different times and are dried separately in the original drier still maintained in the same position and fall on to a steel tray conveyor at B in Fig. 3, which was also supplied by Boby and Co. This conveyor is of a similar type to that already described but is 18in. wide and at 66ft. centres. It is direct-driven by a 4-h.p. motor running at 960 r.p.m. through a totally enclosed worm gear and chain. The capacity of this conveyor is approximately 13 tons per hour. The material next falls into the boot of a chain-bucket elevator 10in. wide by 56ft. centres, which takes the material to the top of the building at C. The buckets are of ⅛in. steel with a mild-steel reinforced lip, and, as the elevator is inclined, they are fitted at the back with double rollers. The elevator is more or less of standard type, supplied by Boby and Co., and is driven by a 4-h.p. motor at 960 r.p.m., through enclosed reduction gear and chain.

This elevator deposits the respective materials through a chute on to a horizontal flat belt conveyor 14in. wide by 85ft. long located over the four hoppers which originally fed the Pfeiffer mills. The conveyor is of the normal type supplied by Boby and Co., and is driven by a 3-h.p. motor running at 960 r.p.m. The drive is direct through reduction gear and chain.

The hoppers are now used one for sandstone, one for slag, and two for limestone. Originally it was intended that the material should be removed from the belt by ploughs, but after a few months' running it was found that the wear of the belt was too heavy and the ploughs have been replaced by a throw-off carriage.

Fig. 2 shows the arrangement of the machinery. After running the plant a short while it was decided to install a small secondary crusher to reduce the limestone to about ¾in. and under and so increase the capacity of the raw mill. This machine is installed at Y in Fig. 2 and the belt conveyor has been slightly raised at the end to accommodate the modified arrangements. The second crusher is of the 24-in. " B " disk type, manufactured by Hadfields.

Underneath the four feed hoppers (Fig. 2) is a second conveyor. This is a troughed belt, 14in. wide by 80ft. centres, driven in a similar manner to the conveyor already mentioned. This belt collects the three materials from the hoppers. The material reaches the belt by feed tables, 3ft. 3in. in diameter and driven separately by motor and worm-reduction gear.

Raw Material Grinding.

The main unit in this section is a Vickers-Armstrongs three-compartment compound tube mill, 6ft. 6in. diameter by 32ft. long. The first and second chambers are lined with chrome steel plates, stepped in the first compartment and plain in the second, while the finishing chamber is lined with hard cast-iron bricks. The intermediate and end diaphragms are of cast steel. The mill is charged as follows: First chamber, 6 tons of 3½in. to 2½in. 0.8 per cent. carbon forged steel balls; second chamber, 8 tons of 2½in. to 1½in. carbon forged steel balls; third chamber, 12 tons of 1in. to ¾in. hard cast-iron balls.

The drive is by a 400-h.p. G.E.C. motor running at 368 r.p.m. already in stock at the works, and a new reduction gear by David Brown was supplied to connect to the mill countershaft. The drive is through a cast-steel pinion on the mill countershaft and a cast-steel driving gear bolted to the feed trunnion head. The mill was designed for a capacity of 10 tons per hour of the raw material when fed with pieces of 1in. and under, the residue being 8 per cent. on the 170-mesh sieve. In practice the mill grinds approximately 11 tons per hour to between 9 and 10 per cent. residue on the 170-mesh sieve, which is sufficient for the purpose.

Coupled to the mill, and drawing air from both the outlet and inlet ends, is a Visco-Beth automatic-suction scavenger-type dust collector consisting of three compartments, each compartment having twelve tubes 10ft. high. As the moisture content of the material is small, say 2 per cent. maximum, no heater or separate scavenging fan was necessary. The dust-collecting plant is coupled to the main suction fan, driven by a belt from a 6 h.p. motor running at 1,440 r.p.m.

Transport and Mixing of Raw Meal.

The most important part of the alterations is the Fuller-Kinyon system of conveying, storing, and mixing the raw meal. The installation comprises two conveying systems, one from the grinding department to the silos, called the "mill stream," the one from silo to silo or to the kiln feed hopper, called the "circulating stream." Both systems are synchronised to function as a unit under a timed automatic control to blend the raw material; this we will call the "blending system." Although the two conveying systems are both connected to the blending system, they can operate separately or simultaneously at the will of the operator.

THE MILL STREAM.—This conveying system is composed of a standard type 5-in. stationary Fuller-Kinyon pump, receiving the raw material directly from the tube-mill. This pump is connected to a 3½in. diameter conveying line, and conveys and delivers the raw material to any of four silos according to prede-

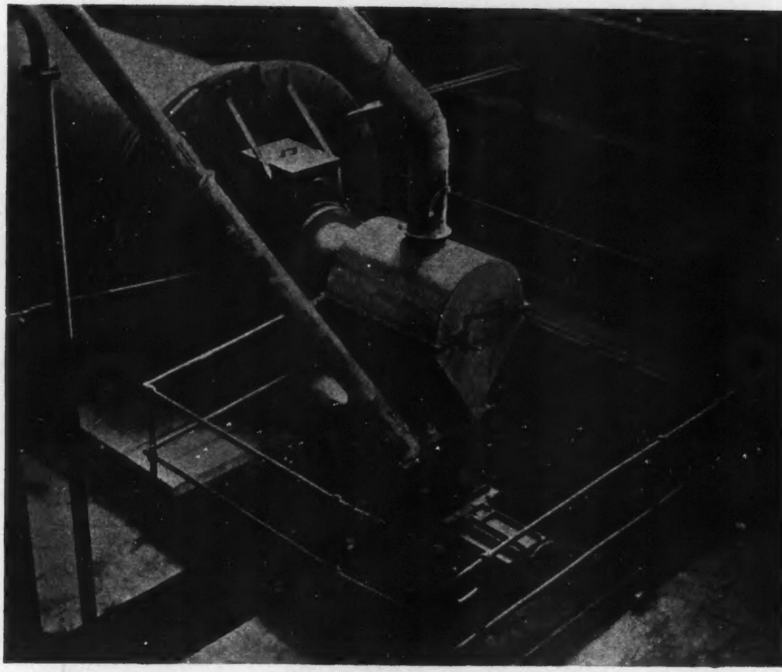


Fig. 4.

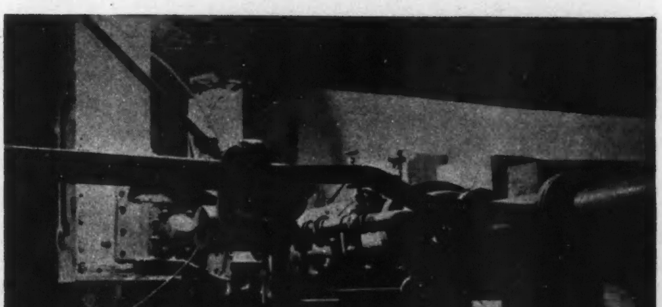


Fig. 5.

termined cycles and lengths of time, and is operated under remote control from the laboratory as described later. The length of the line is 260ft., including a vertical lift of 55ft. The pump is direct driven by a G.E.C. motor rated at 15 h.p. and running at 960 r.p.m., and has a maximum hourly capacity of 11 to 12 tons. The compressed air delivered at the pump is used under a pressure of 12 to 14 lb. per square inch. The average power absorbed per ton conveyed is 1.3 h.p. for both the pump motor and compressed air. Fig. 4 illustrates the assembly of the Fuller-Kinyon pump and the discharge hood of the tube mill.

CIRCULATING-STREAM AND DELIVERY OF RAW MATERIAL TO KILN FEED HOPPER.—This system is composed of a 6in. type F stationary Fuller-Kinyon pump,

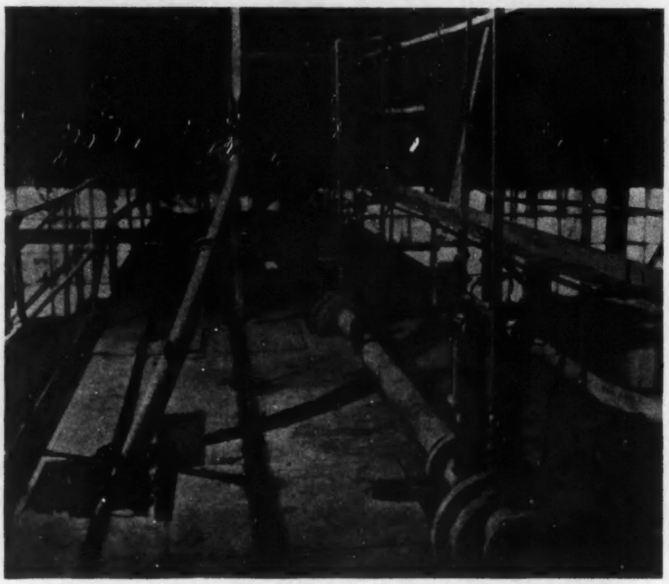


Fig. 6.

receiving raw materials from any of the four silos, separately or simultaneously and in variable proportions. From the silo outlets the material is fed to the pump hopper by two screw conveyors with a total hourly output of 30 tons. A third screw conveyor brings to the pump hopper the flue dust collected in the kiln-dust settling chambers. This is a good method of uniformly disposing of the dust. The system is found to work well, and not only gets rid of what would otherwise be a nuisance, but does so in a practical way by distributing evenly very small proportions throughout the mass of raw materials being circulated and blended. The 6in. pump works in combination with a 5in. conveying line, delivering the raw material to any of the four silos and to the kiln bin over a

total length of 115ft., including 60ft. of vertical lift. The pump is driven by a 25 h.p. G.E.C. motor running at 960 r.p.m. The air pressure admitted at the pump varies from 12 to 16 lb. per square inch. The total power absorbed per ton conveyed averages 1 h.p. for the pump motor and compressed air. Fig. 5 shows this pump, and Figs. 6 and 7 show the conveying lines and their various branches on top of silos with branch line to the kiln bin.

The compressed air necessary for both pumps is supplied by one Reavell reciprocating air compressor. This compressor is of the vertical type, single stage, and can deal with 400 cu. ft. of air per minute at a maximum pressure of 30 lb. per square inch ; it works normally at a pressure of from 20 to 22 lb. when both pumps are operating under full capacity. The compressor is driven by a 50 h.p. G.E.C. motor running at 460 r.p.m. A small auxiliary "garage" type

Fig. 7.

Reavell compressor, driven by Tex rope from the main compressor flywheel, and dealing with 3 cu. ft. of air per minute, is also installed to operate separately the electro-pneumatic valves to which it delivers compressed air at 50 to 60 lb. per square inch. It is just possible to operate these valves by the low-pressure air generated by the main compressor, but with the higher pressure the valves operate more smartly and satisfactorily.

The main compressor delivers air to a 36in. diameter by 6ft. high air receiver complete with the necessary arrangements for draining, etc., and the small compressor delivers air to a small receiving vessel alongside. The main compressor also delivers compressed air to two air nozzles in each raw material silo for breaking up any arches which may be formed by the material.

(To be continued.)

Notes from the Foreign Press.

Removal of Clinker Rings.—By F. Kremer (*Tonindustrie Zeitung*, 1935, p. 484.)—This is an amplification of a former article (T.Z., 1935, p. 199). Only two methods generally applicable are at present available for removing clinker rings, namely, burning and breaking off. Burning off of clinker rings is attended with great risk of injury to the kiln lining and is difficult to perform, whereas it is nearly always possible to break off even the hardest rings with steel pokers. The poker which has been found most useful is square in section with an edge 40 to 50 mm. long; the length is limited by the ability to handle it and the time it is in the kiln, as if it is allowed to get too hot it will bend. Several pokers must be available to replace those that become too hot.

Patents have been taken out for mechanically-operated water-cooled pokers. Good results have been obtained by directing a jet of water on to the clinker ring, but this tends to cool the kiln too much and to injure the lining. A long series of tests was carried out with a hollow steel poker with a nozzle screwed on to the end, with the opening facing downwards. Water was pumped through this tube and could be directed on any part of the clinker ring. Now and again very good results were obtained without injury to the lining, but the nozzle was often choked and put out of action. As the nozzle had a larger diameter than the poker it sometimes became firmly stuck in the clinker ring and was very difficult to move.

A suggested method is to alter the composition of the raw material by raising the silica and lime content. This necessitates a higher burning temperature, and the ring may be burnt away. Clinker rings do not form so readily with this type of raw material; brittle clinker rings which are easily broken off are produced when the coal ash is high in silica and low in fluxes and high SiO_2 content in the raw material is used.

Improvements in the Burning of Cement.—By H. Jordan (*Zement*, 1935, p. 395).—This article reviews German patents taken out during 1934 relating to improvements in the construction of shaft kilns and moving grates for burning Portland cement.

Brownmillerite Cement.—By F. Ferrari (*Tonindustrie Zeitung*, 1935, p. 533). —It is pointed out that Professor Ferrari was the first to suggest cements in which the percentage of Al_2O_3/Fe_2O_3 is 0.64, and that therefore cements of this type should really be called " Ferrari cements."

The raw materials required for the manufacture of this cement are a substance high in silica, iron oxide (calcined pyrites), and the usual raw material for Portland cement (limestone, clay, pozzolana, blastfurnace slag, etc.). Quartz sand can be used for the first if it is sufficiently finely ground or kieselguhr, Radanit, tripoli, moler, gaize, Si-stoff, etc., may be used. The raw material is easily sintered and has many advantages from a works point of view. It is not necessary to exceed a fineness of 4 to 5 per cent. on the 4,900-mesh sieve to obtain high strengths. The finished clinker consists of $3CaO.SiO_2$ and $4CaO.Al_2O_3.Fe_2O_3$ if lime saturation is reached ; if not there is also some $2CaO.SiO_2$ present.

The following results were obtained for such a cement having a silica ratio of 3 and a fineness of 4 to 5 per cent. on the 4,900-mesh sieve. Setting time : Initial, 3 to 4 hours ; final, 6 to 7 hours. Tensile strength (lb. per sq. in.) : 3 days, 500 to 640 ; 7 days, 640 to 780 ; 28 days, 780 to 920. Compressive strength (lb. per sq. in.) : 3 days, 6,400 to 7,100 ; 7 days, 8,500 to 10,000 ; 28 days, 10,700 to 12,100.

The tests were made according to the Italian standard specification.

Concrete made with this cement has good workability, low heat evolution, low shrinkage, and high chemical resistance. With a lower lime ratio the setting time is increased, hardening is slower, workability is somewhat less, shrinkage is less, heat evolution is lower, and chemical resistance is greater. The cement should be suitable for mixing with pozzolana and basic blastfurnace slag.

Estimation of Free Lime in Hardened Cement, Cement-Trass Mixtures and Combined Calcium Hydrate in Hardened Lime-Trass Mixtures. By V. Rodt. *Zement*, p. 94, 1935.—In the last article on this subject (*Zement*, p. 429, 1934, abstract *C. & C.M.*, 1934, p. 358) results were given for specimens which had hardened in the atmosphere. This article deals with specimens which have hardened for six months in air free from carbon dioxide, and the following results were obtained. The addition of trass to Portland cement did not lower the amount of free lime. Blast-furnace cements contained much less free lime than Portland cement. In lime-trass mixtures large amounts of lime go into combination at early dates and the rate of combination falls off at late dates. There does not seem to be any direct relation between the amount of combined lime in the lime-trass mixtures and the capacity for hardening.

Estimation of Free Lime in Portland Cement.—By A. Hanslitschek (*Tonindustrie Zeitung*, 1935, p. 556).—A number of methods of estimating free lime in Portland cement have been tested by the author and the results discussed.

Recent Patents Relating to Cement.

Cements.

430,781. Forsen, L., Limhamn, Malmö, Sweden. Sept. 4, 1934.

Portland cement is rendered water-resistant by mixing the ground cement with a material such as a clay containing more than 50 per cent. of kaolin substance, $Al_2O_3.2SiO_2.2H_2O$, which has been burnt at 500 to 1000 deg. C., the proportions of cement and clay being so chosen as to give a final mixture containing at least 1 molecule of kaolin anhydride, $Al_2O_3.2SiO_2$, to 2 molecules of tricalcium silicate, as calculated by Bogue's formula for the cement. Accelerators such as neutral or basic calcium chloride or aluminium chloride may be added.

Cements.

431,060. Lalin, G. S., 90, Skeppare-gatan, Stockholm. (Assignee of Aktiebolaget Vallevikens Cementfabrik, 10, Fredsgatan, Stockholm). Dec. 29, 1933.

A cement having a rapid initial set, e.g. within 12 seconds, and a sufficiently slow hardening speed to avoid the formation of cracks by the evolved heat, comprises a mixture of aluminous cement and Portland cement or other calcium silicate cement free from gypsum or other retarding agent. The cement may be made by mixing the two kinds of clinkers, e.g. in proportions from 1 to 3 to 3 to 1, and grinding. The cement is specially intended for the repair of walls and masonry through which water is seeping, the cement being applied by a cement gun to the moist surface of the structure remote from the water pressure. It may also be used in building construction, layers of the cement being applied by a gun or otherwise.

Coloured Cement Compositions.

431,680. Dewey & Almy, Ltd., Angel Road, Edmonton, London. Nov. 8, 1933.

Coloured concrete is prepared by mixing, with a mix containing water, a calcareous substance and a colouring material, an agent in the form of a soluble organic compound containing a number of aromatic nuclei directly attached to an aliphatic nucleus. This agent disperses the cement and pigment particles uniformly through the mix and allows a diminution in the quantity of mixing water. The agent may have the general formula $A.R.A^1SO_3M$, where A and A^1 are two or more like or unlike aromatic groups joined to an aliphatic nucleus R comprising a single alkyl group or a number of alkyl groups associated in straight chain or branched chain formation, and SO_3M is at least one free sulphonic acid group or a sulphonic acid group in combination with a soluble salt forming radicle. They may be prepared by condensing a sulphonic acid of an aromatic hydrocarbon or a derivative thereof, e.g., β naphthalene sulphonic acid, with formaldehyde or a substance capable of supplying formaldehyde. The cement, colouring material, and dispersing agent may be mixed dry ready for incorporation as part of a concrete mix.

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